Space Weather Technical Forecast

Issued on Wednesday, 13 December 2023 at 13:19 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Chance of isolated M-flares. Chance of Active-G1 Minor Storm intervals day 4 (16 Dec) from CME arrival.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Low with a number of C-flares, peaking C8.2 at 12/1342 UTC from AR3514. There are seven numbered sunspot regions. AR3514, while relatively small, remains the most notable, with ongoing flux emergence, north-south orientation of its magnetic field, and the presence of a weak delta-spot configuration. Nearby growth, currently attributed to AR3517 may also destabilise this region further. AR3519 recently emerged in the southeast, but remains relatively small and simple. All other regions are small, and either stable or declining.

A faint, but broad CME was observed leaving the Sun to the northwest on SOHO imagery around 13/0100 UTC. This has been attributed to the LP C2.9 flare of AR3519 and an associated dimming that started at 12/2215 UTC. Analysis is ongoing, however a relatively slow Earth-directed CME is expected, currently anticipated to arrive on day 4 (16 Dec).

Solar Wind / Geomagnetic Activity: Solar winds as observed by ACE and DSCOVR at L1 were at background, below 400 km/s. Density was below average to average. Total Interplanetary Magnetic Field (Bt) was initially Moderate at 13nT, but declined to be weak from 12/1500 UTC, varying 5-7 nT with the north-south component (Bz) initially at -10nT, but became variable between +5 nT and -5nT from 12/1500 UTC. Phi angle was predominantly positive (away from the Sun), with brief periods of negative (towards the Sun). Geomagnetic activity was Unsettled at first (12/1200-1800 UTC), but then eased to be Quiet (Kp1-2).

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux remained at background levels. GOES16 high energy (greater than 2MeV) electron flux briefly peaked at high levels 13/1425 at 1120pu, before quickly declining to background. The 24-hour fluence was below the Active threshold (1e8 integrated pfu). The observation at 13/0000UTC was 1.46e7 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: Low to Moderate activity is expected with a chance of M-class flares, primarily from AR3514.

Solar Wind / Geomagnetic Activity: The CME that occurred on 13 Dec from AR3514 is currently expected to arrive on day 4 (16 Dec) however analysis is still ongoing. Otherwise currently background winds are likely to enhanced from the arrival of the fast winds of CH79 on day 2 and into day 3 (14-15 Dec), before easing thereafter. Winds are likely to peak elevated, at around 500-550 km/s, however confidence is currently low in both timing and peak wind strength. Mainly Quiet geomagnetic activity at first is forecast to become Unsettled to Active day 2 and into day 3 (14-15 Dec), with a slight chance of an isolated G1 Minor Storm interval, before easing later day 3 to Quiet with isolated Unsettled intervals. There is a chance of a spell of Active to G1 Minor storms on day 4 (16 Dec) from any CME arrival.

Energetic Particles / Solar Radiation: GOES16 high energy proton is expected to persist at background levels, with only a very slight chance of rising towards the S1/Minor Radiation Storm

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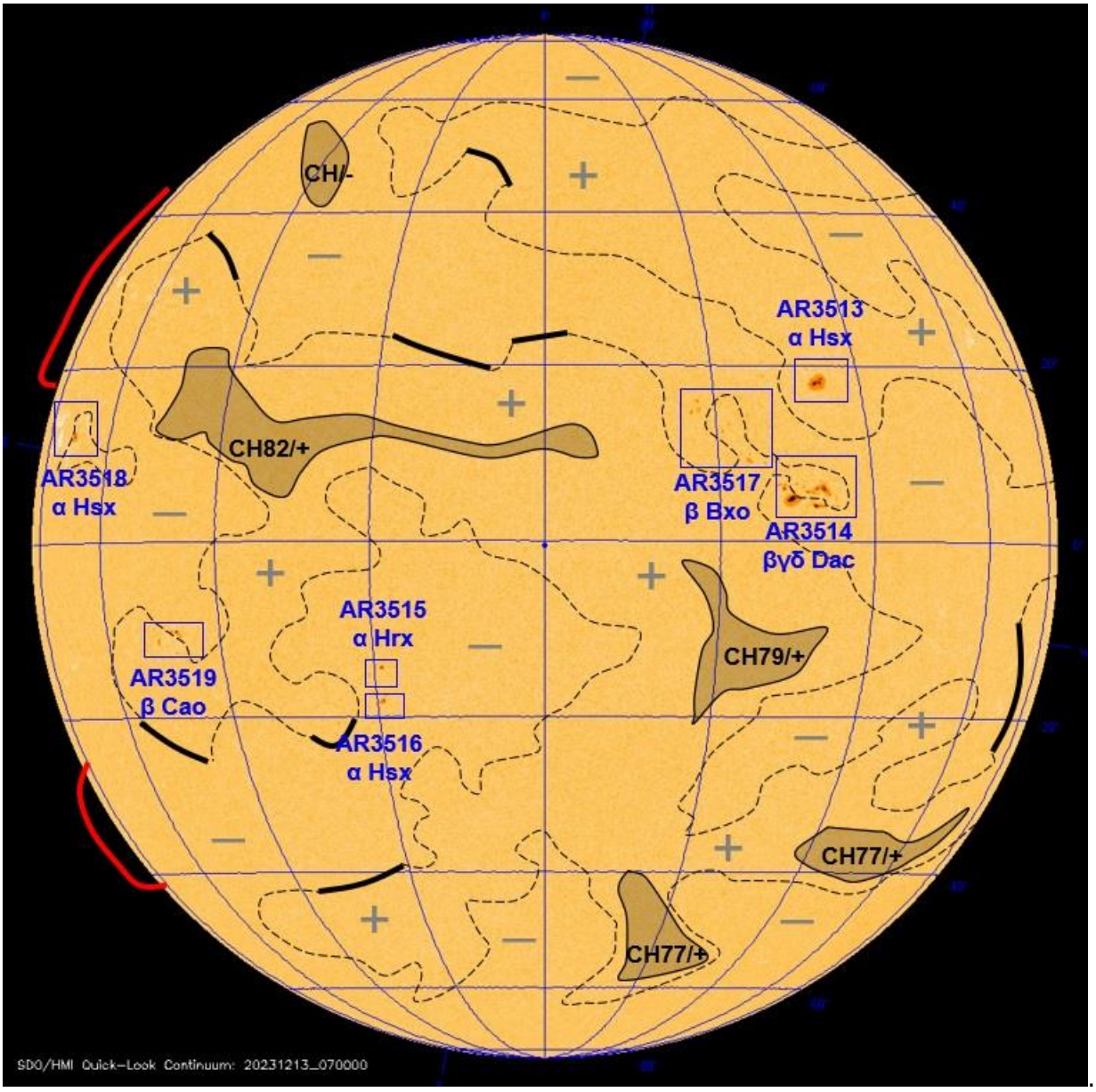
level given any significant flares from AR3513 or AR3514. High energy electron flux is expected to be background at first, recovering to moderate levels during Day 1 (13 Dec) and may briefly combine with diurnal peaks Day 1 and 2 (13-14 Dec) to venture into the high threshold, although this is considered only a slight risk. A further suppression is anticipated some point from Day 2 following the anticipated HSS enhancement from CH79/+.

Figure 1. Solar Analysis Valid 13/2000 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

A CME has been observed with potential for an observable impact at Earth. This was associated with a LP C2.9 flare around from AR3514 in the northeast, and produced a faint but relatively wide partial halo with a clear coronal dimming that started around 12/2215. Analysis is still ongoing, however a preliminary assessment suggests arrival around the middle of day 4 (16 Dec).

Further weak CMEs have been observed from AR3514, including from the C9.0 flare at 12/0350 UTC, and from the C1.8 flare 11/2228 UTC. However these are narrow, faint and very low confidence, and considered unlikely to have any noticeable impact.

Current background winds have the potential to become elevated day 2 and into day 3 (14-15 Dec) due to the onset of any fast wind from CH79/+, perhaps peaking around 500-550km/s, Confidence is low in the timing and peak wind speeds however, due to the non-persistent nature of this coronal hole, and the MOSWOC enlil model currently dominated by an overestimated influence from CH77/+ in the far south.

Mainly Quiet geomagnetic activity at first is forecast to become Unsettled to Active with any CH onset day 2 and into day 3 (14-15 Dec), with a slight chance of an isolated G1 Minor Storm interval, easing later day 3 to Quiet with isolated Unsettled intervals. There is a chance of a spell of Active to G1 Minor storms on day 4 (16 Dec) from any CME arrival.

Geo-Magnetic Storm	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Minor or Moderate	G1 to G2	No	1	15	10	25
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
13/0555	Partial	Filament and C2.8 flare	AR3514	530 km/s	16/0800 +/- 12 hours	Low confidence – still under analysis. Faint in imagery

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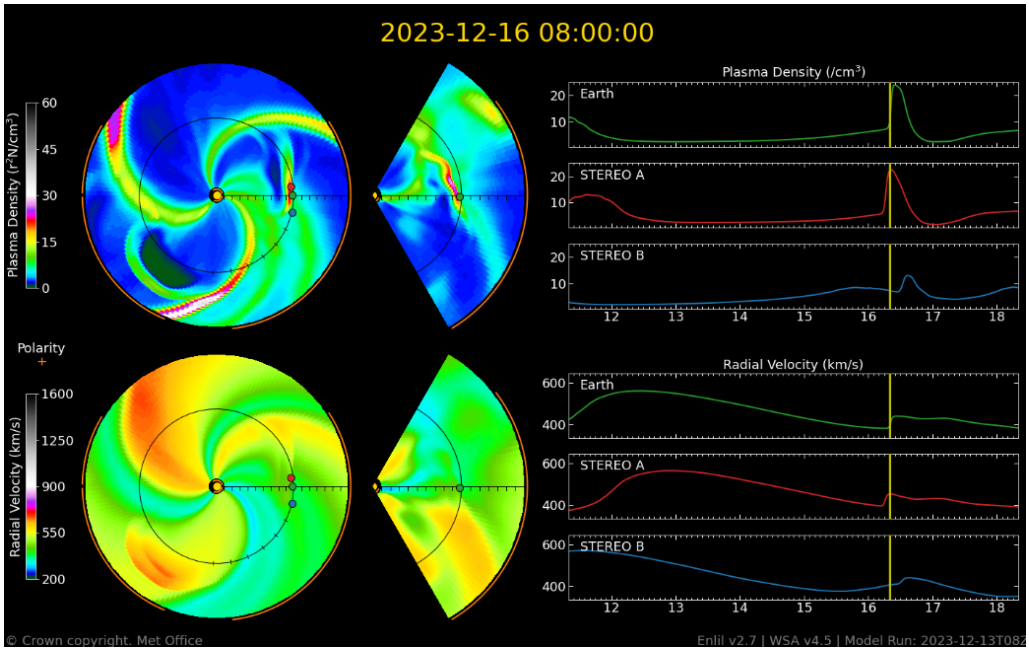
Figure 2a: Enlil and ensemble, showing potential CME arrival



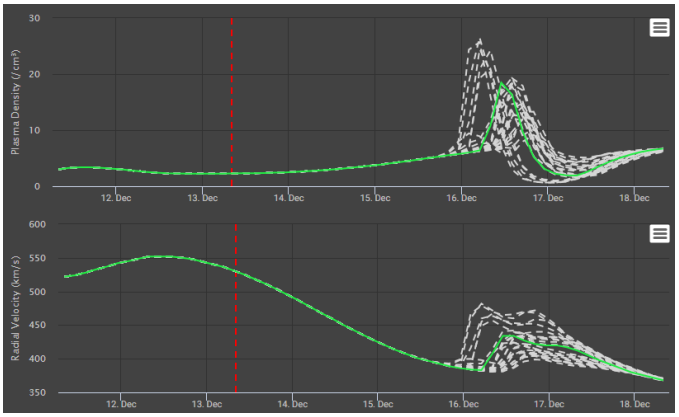
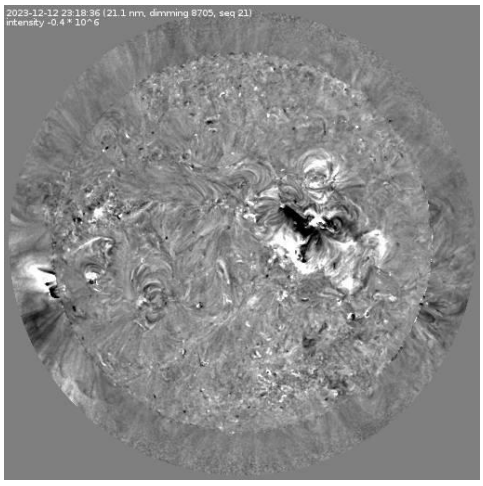


Figure 2b: CME Associated coronal dimming from solar demon (12/2215 UTC).



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Radio Blackouts - X-Ray Flares:

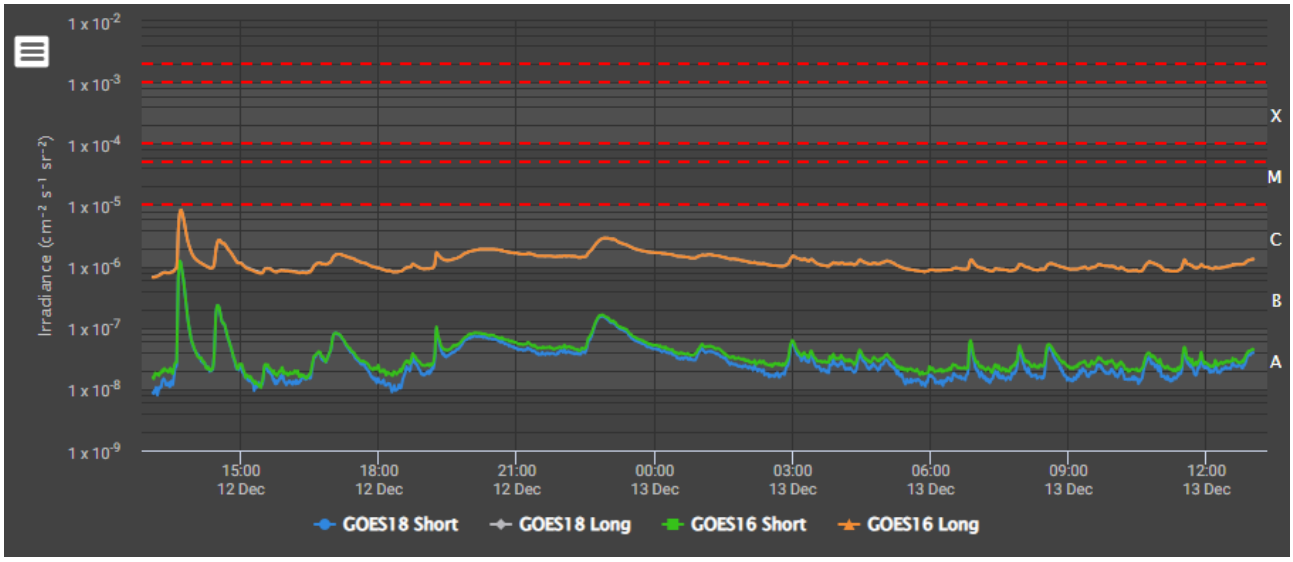
Low to Moderate activity is expected, with a chance of isolated M-flares. There are seven numbered active regions on the disc.

The main source of potential flaring is AR3514, which is seeing ongoing flux emergence as it moves across the northwest disc. While still relatively small sized, this is a compact group with an E-W parity separation line, often conducive to flare production. Some mixing of the regions polarity is also evident, with a weak delta spot identifiable near its main trailer spot. Despite this, flare activity remains limited, however this development does increase the potential for M-class flares, and with continuing growth, there is a very slight chance of X-class flares.

While small, some growth has also been observed in a small region to the northeast of AR3514 (currently attributed to AR3517, but could be a new region), and also newly numbered AR3519 in the southeast. These also provide an increased M-class flare potential. The other regions remain smaller and simpler.

X Ray Flares Probability	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	R1-R2 M Class	No	45	50	50	50
Very Active	R3 to R5 X Class	No	5	5	5	5

Figure 3: GOES-16/18 X-ray flux



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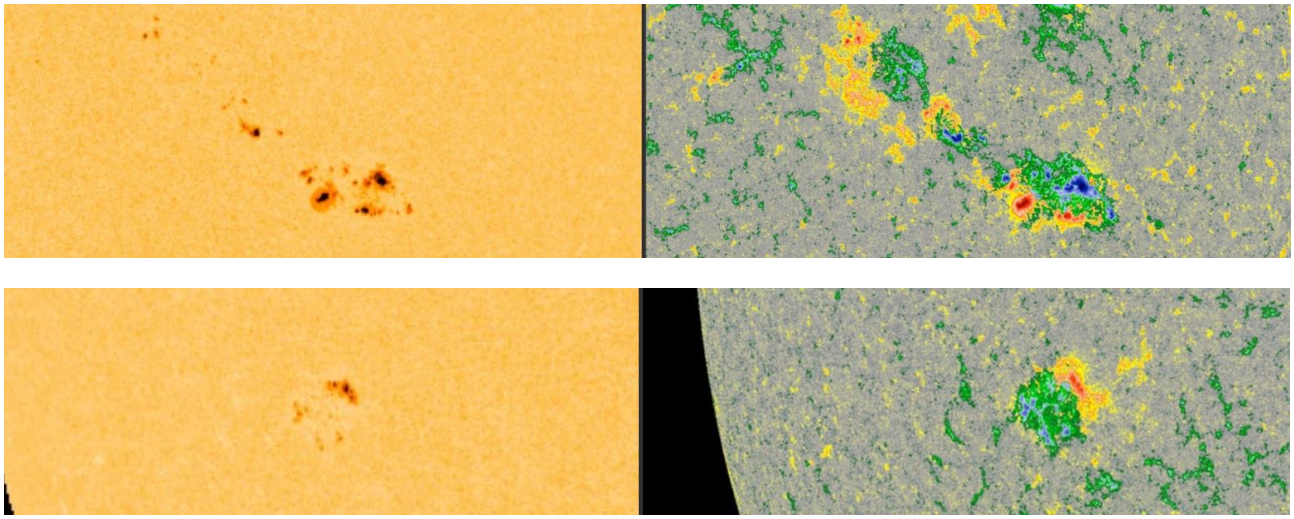
Solar Radiation Storms - (High Energy Protons):
The high energy (greater than 10MeV) proton flux observed by GOES16 is currently at background levels. There is a slight chance of this increasing should there be any significant flares. The main risk is currently AR3514 as it develops and moves towards the northwest limb.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	≥ S1	No	5	5	5	5
Very Active	≥ S3 *	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: SDO Hmi-intensitygram and Magnetogram of AR3517, new emergence and AR3517 (from left to right) in the northwest disc (top) and AR3519 in the southeast disc (bottom).



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High Energy Electrons Event (≥ 2MeV):

High energy electron flux, as observed by GOES-16, is currently at background. The timing and strength of solar winds enhancement from CH79/+ is low confidence, but is currently expected to be relatively weak, occurring on day 2 or day 3 (14-15 Dec). This will limit the extent of any increased flux through the Van Allen Belts, with observed flux rising to Moderate, perhaps briefly touch High on day 3 and into day 4 (15-16 Dec). The arrival of a CME on day 4 (16 Dec) is then likely to return flux to background.

The associated 24 hour fluence is expected to remain below the Active threshold, but may rise closer to the Active threshold by the end of the period, depending on the timing and strength of the next anticipated HSS, and any subsequent CME impact on day 4 (16 Dec).

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	1	1	5
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

Figure 5: GOES-16 >2MeV Electron Flux and 24hr Fluence with REFM

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